Electricity Demand in Ontario – A Retrospective Analysis

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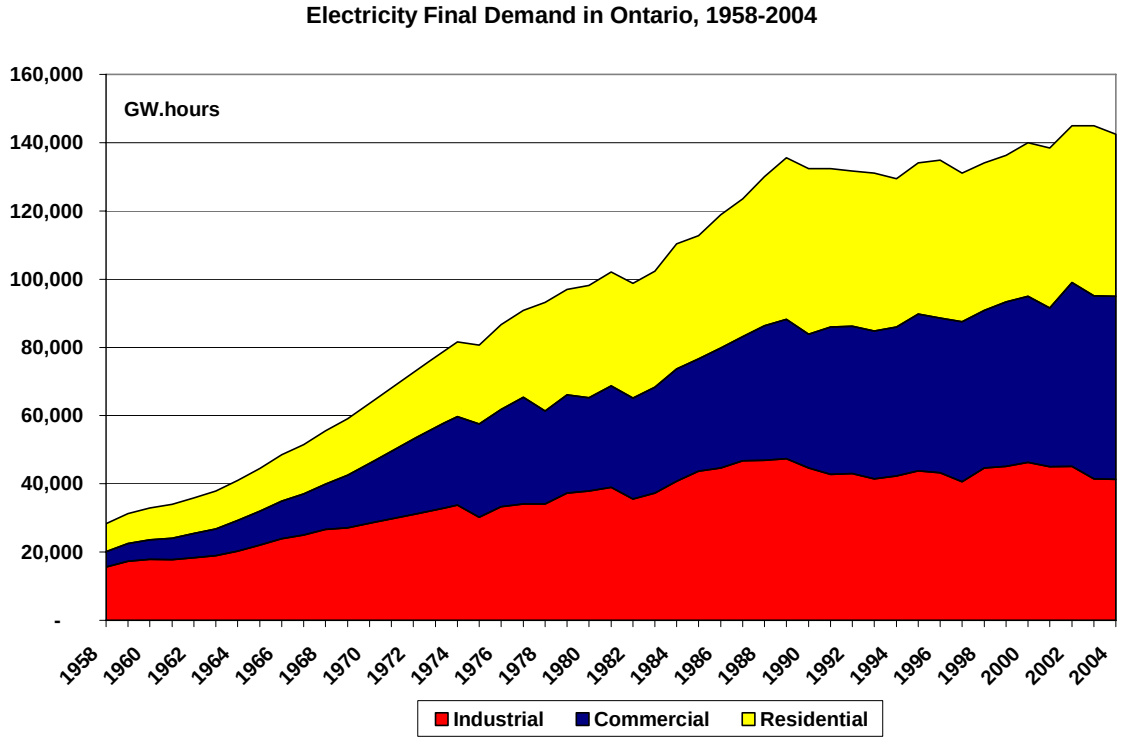
1. Introduction & Overview of Electricity Demand

Since 1958, the demand for electricity has increased fivefold, from 28,000 GW.hours to over 140,000 GW.hours in 2004. Over this long term, growth averaged 3.8 percent per year but it has been slowing down in recent years. There has also been a shift over the years in the share of total demand from each of the main consuming sectors. In 1958, the industrial sector accounted for 55 percent of Ontario's electricity use and commercial and institutional buildings only 16 percent; today the industrial share of electricity demand has dropped to 29 percent and commercial and institutional buildings account for fully 38 percent of total demand.

Figure 1



As shown in Figure 2, there has also been a transformation in the supply of electricity over this period. In 1958, most of Ontario's electricity was supplied by hydroelectric power from the large power dams on the St. Lawrence River, at Niagara Falls, and various other sites around the province. There has been little growth in the supply of hydropower since then, however, and the current system relies on a mix of coal, nuclear, hydro, gas and other power plants.

Figure 2

Electricity Generated in Ontario by Source, 1958-2004

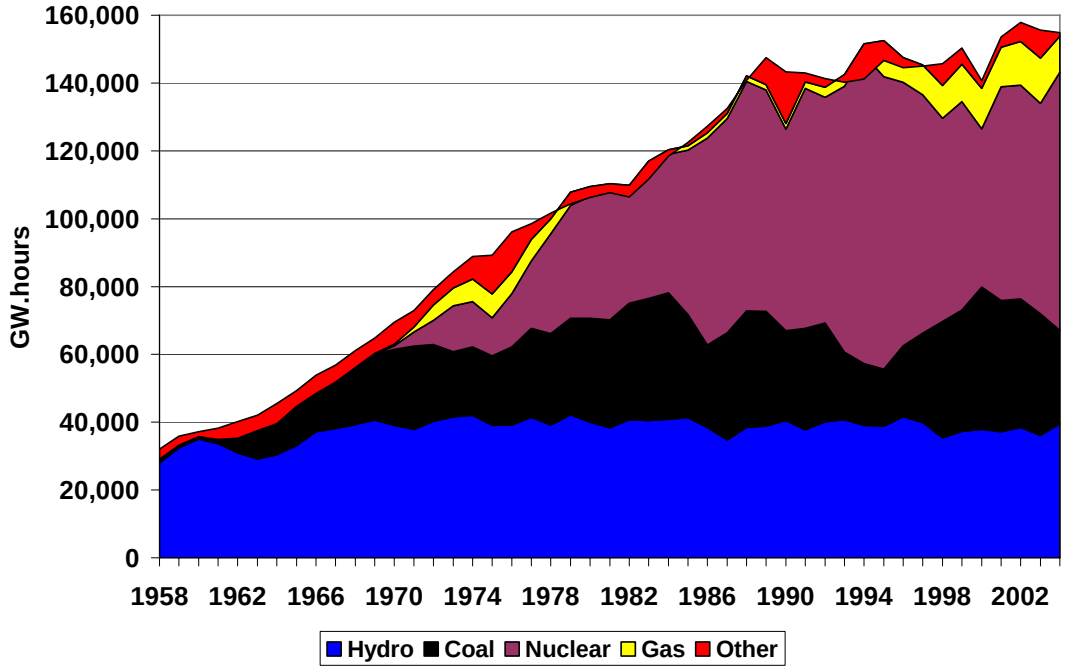


Figure 3

Final Demand for Fuels and Electricity in Ontario, 1958-2004

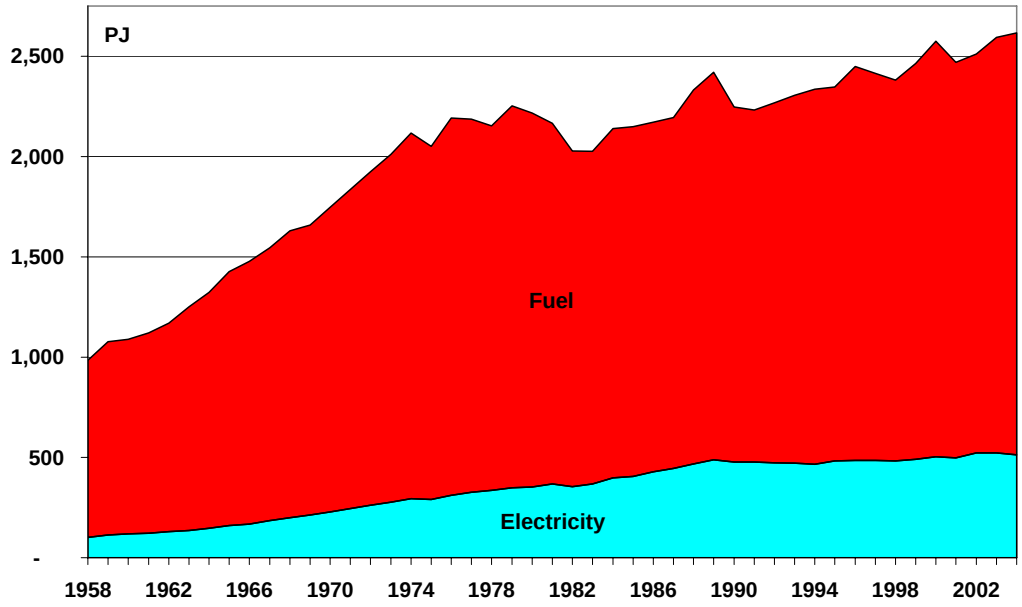
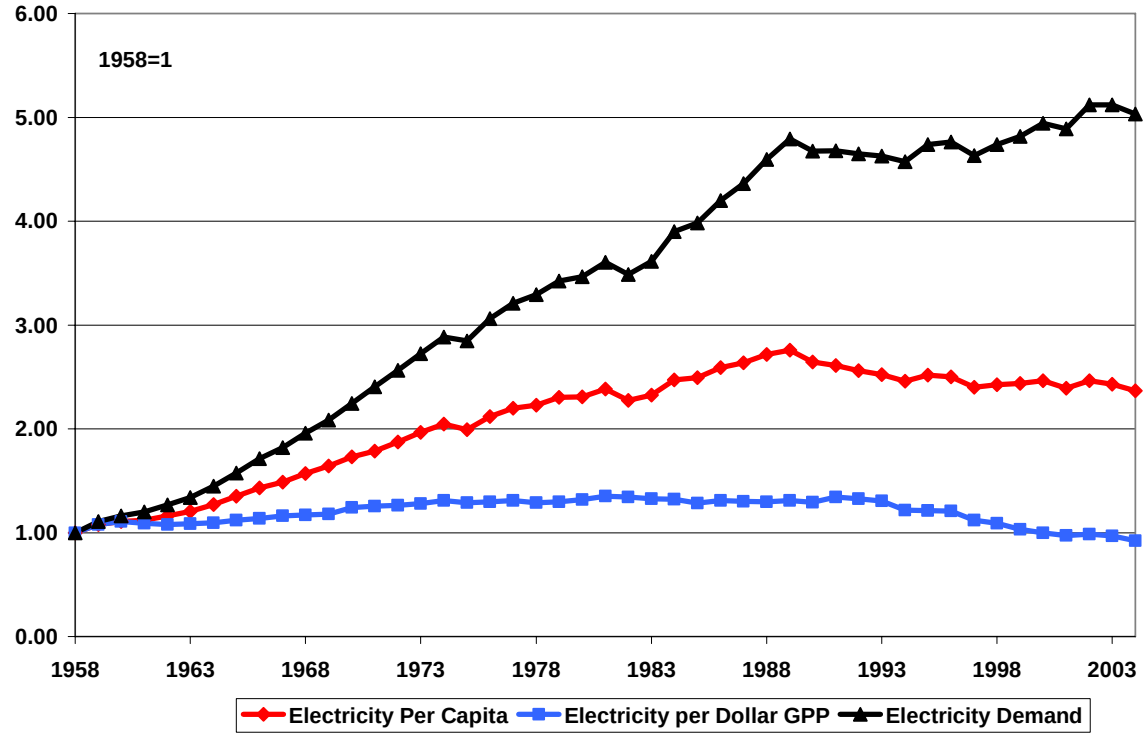


Figure 3 illustrates the contribution of electricity to Ontario's total demand for energy. About 12-14 percent of our energy use consists of applications that can only be provided with electricity: lighting, small motors and appliances, electronics, etc. In addition to this "captive market", electricity is also used to provide space and water heat, boosting its overall share of Ontario's energy use to 21 percent.

The overall pattern of electricity demand is illustrated in Figure 4 over the 1958-2004 period. After 30 years of steady growth, the demand for electricity started to decelerate in the 1990's Per capita electricity demand peaked in 1988 and was down by 15 percent by 2004. The electricity intensity of the economy, expressed in electricity demand per dollar of GPP leveled off in the 1970's and has been declining since the early 1990's. In fact, the electricity intensity of the Ontario economy in 2004 was lower than it has been in fifty years.

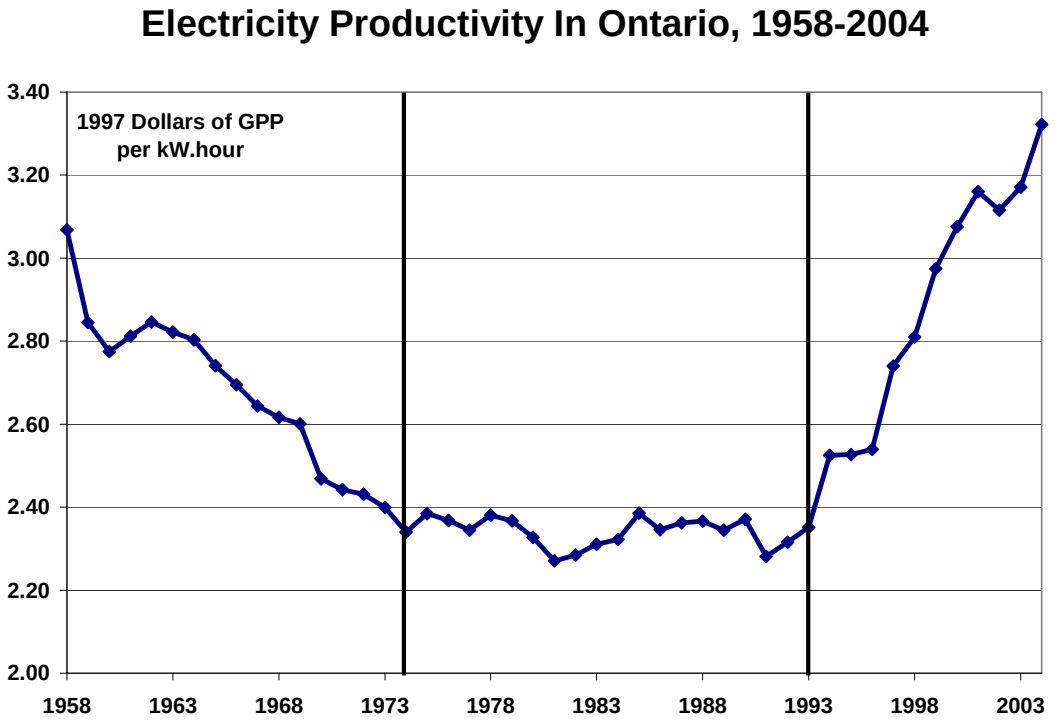
Figure 4

Relative Growth in Electricity and Electricity per Captia and per Dollar of GPP, 1958-2003



A closer look at the long term trends reveals that there have been three distinct phases in the evolution of the demand for electricity in Ontario since 1958. These phases are best illustrated by tracking the trend in the electricity productivity of the Ontario economy – the dollars of economic output generated per kilowatt-hour of electricity used. This indicator – the inverse of the electricity intensity illustrated in Figure 4 – is illustrated for the 1958-2004 period in Figure 5.

Figure 5



In the first phase, from 1958 to 1974, electricity demand grew at nearly 7 percent per year while the economy grew at 5 percent and the population at 2.2 percent. The economy was booming and the "Live Better Electrically" advertising campaign encouraged the use of electricity for space and water heating. Large coal-fired power plants were built to meet the growing demand.

From 1974 to 1993, electricity demand growth rates slowed down but not as much as for other fuels. While the demand for oil and gas fuels "decoupled" from GPP growth, electricity demand continued to grow at the same rate as the economy, about 2.5 percent per year, prompting Ontario Hydro to put forward a capital expansion program consisting of dozens of coal and nuclear power plants.

The third phase of electricity productivity in Ontario began in the early 1990's and is ongoing. During this period, Ontario's economic growth and electricity growth curves diverged sharply. While the economy grew at an average rate of 4 percent (and population growth continued at 1.4 percent), electricity demand growth has averaged 0.8 percent per year. This period corresponds to the restructuring of Ontario Hydro, the shutting down of utility demand side management programs, and a cessation of capital investment in large new power plants. The output of the nuclear program peaked during this period and began to decline.

It is this third phase, from 1993 to 2004, that is the subject of the rest of this analysis.

2. Electricity Demand in Ontario, 1993-2004

The Big Picture

Between 1989 and 1993 the Ontario economy went into recession, and the demand growth for electricity stalled with it. Given the strong correlation between economic and electricity growth rates throughout the 1970's and 1980's, the slowdown in electricity growth was initially attributed to the economic downturn. But when Ontario's economic output returned to pre-recession levels in 1994 and began to grow again, electricity growth did not rebound with it. In retrospect it is now apparent that the economy that emerged from the recession was less electricity-intensive than the pre-recession economy and that economic growth and electricity demand growth had "decoupled" in the manner that petroleum demand and the economy had decoupled twenty years earlier.

The electricity productivity of the economy – the GPP produced per kilowatt-hour of electricity consumed – is an aggregate indicator and reflects both the structure of the economy and the technological efficiency of electricity use. A relative shift in output from electricity intensive activities such as smelting and paper making toward general manufacturing or services will cause electricity productivity to increase. The same effect is caused by shifts within the electricity intensive industries toward higher value-added output. The electricity productivity of the economy will also improve if there is a shift away from the use of electricity for heating applications, or if the efficiency of electricity using technologies, from lights to computer screens, improves. All of these factors have been at work in Ontario over the past fifteen years, although there is very little research and understanding of their relative importance.

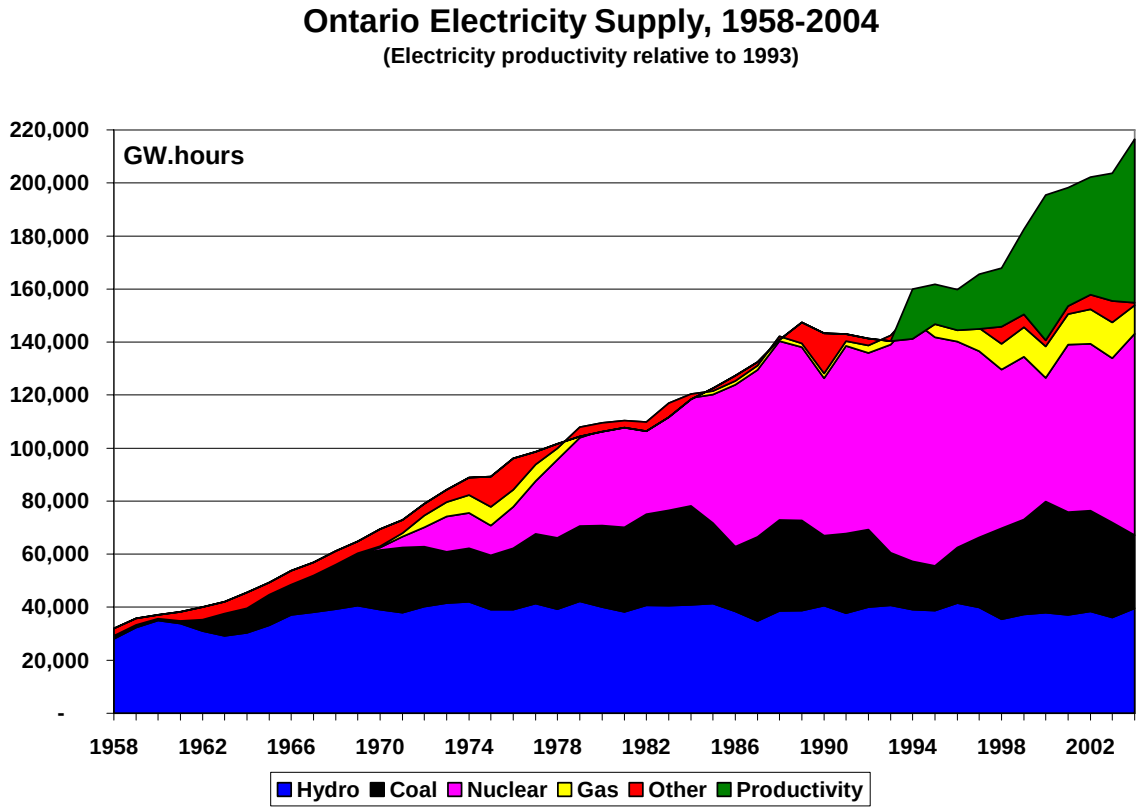
What is clear from the aggregate indicator illustrated in Figure 5 is that the electricity productivity in Ontario is now higher than it has been in fifty years and that it is continuing to improve on a steep curve.

One way to appreciate the significance of this trend is to think of the electricity productivity as a new "source" of power, and to consider how much additional generating capacity Ontario would have been required in 2004 if not for the productivity improvement that has occurred synced 1993. Viewed this way, as illustrated in Figure 6, electricity productivity emerges as the biggest story in Ontario's electricity economy; by 2004 the productivity improvement was displacing the need for over 60,000 GW.hours of generation, equivalent to 150 percent of the output of all the hydro dams, or twice as much as the output of all the coal plants, or about equal to the power output of ten large CANDUs operating with 80 percent capacity factors.

Considering the size and the economic value of the productivity "resource", we have a relatively poor understanding of its makeup and internal dynamics, for example how much is due to fuel switching and technology efficiency improvements and how much is due to structural change in the economy. We can see from the aggregate statistics that the services sector has been growing faster than the manufacturing sector in Ontario and this will generally result in an increase in

electricity productivity, but in general there is a dearth of data and quantitative analysis for understanding both the historical trends in and the future potential for electricity productivity improvement in Ontario.

Figure 6



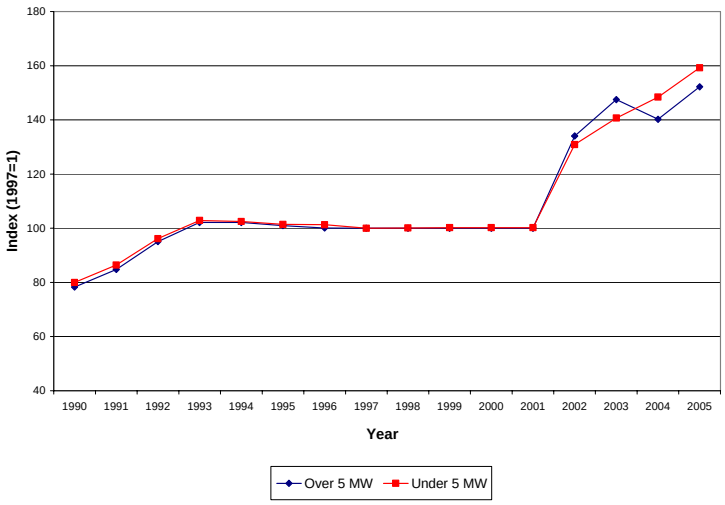
It is interesting to note that the electricity productivity improvements took place during a period in which electricity prices were generally either stable or declining and during which utility demand side programs all but disappeared from the Ontario electric market. Electricity prices did increase in the period leading up to 1994, but remained then declined slowly until the rates were partially unbundled in 2001 in preparation for Market Opening. **Error! Reference source not found.** provides a price index showing how electricity prices changed over the period for industrial customers with greater than and less than 5,000 kW demand per month. The pattern of price changes for residential and commercial/institutional customers would have been similar up to the point of market opening.

While electricity prices increased by approximately 20 percent in the early 1990s, public perception of this increase may have differed from the actual price change. Announcements by the Minister of Energy at that time led consumers to expect that there would be a 45 percent price within a few years. While that price increase didn't occur, consumers may have responded based on their expectations of future prices.

In May 2002, the Ontario electricity market was opened to competition. At that point, electricity charges were "unbundled" to separate out elements that were open to competition from those that were deemed to be 'non-competitive'. After May 2002, individual customers may have paid commodity costs based on market prices or a contract price received from a Retailer. At the opening of the market, approximately 15 to 20 percent of residential customers had contracted with a Retailer for commodity. Generally these prices were above what eventually became the fixed or capped price for commodity.

For customers who did not choose to contract with a Retailer, commodity prices were based on the Wholesale Spot Price from May 2002 to December 2002. In December 2002, the government capped the commodity price for approximately 50 percent of the market or about 98 percent of participants. This meant that small volume consumers and most institutional customers paid a fixed price for commodity (4.3¢ per kWh) while larger accounts (generally those with demands over 50 kW per month) paid a variable, hourly price based on the spot market. Essentially, most customers saw very little change in electricity prices in the period under review. There was however, considerable uncertainty with regards to both prices and how electricity would be supplied in the last 2-3 years of the period. Consumers also experienced considerable price volatility for the commodity portion of the bill during 2002. The subsequent 'refunding' of some of these costs may also have affected consumers' perceptions of costs.

Figure 7. Ontario Electricity Price Index



The remainder of this report takes a closer look at electricity demand trends at the sector level in Ontario, focusing on the period from 1990 through 2003.

3. Sector Analysis

Method

The analysis of Ontario's electricity use carried out in this report is primarily based on data made available by the Office of Energy Efficiency (OEE) at Natural Resources Canada. The data is published on a national and provincial basis in the "Comprehensive Energy Use Database" (website: www.nrcan.oee.gc.ca). Information for Ontario and more specifically for electricity use in the province was extracted from this database for analysis. Information on energy pricing was obtained from Statistics Canada and from comparisons published by Quebec Hydro.

The OEE reports all energy use in terms of joules (Petajoules {PJ}, Megajoules {MJ}, etc.). In order to make the discussion more relevant to electricity, all values were converted to electrical terms (i.e. kilowatt hours {kWh}, Megawatt hours {MWh} or Gigawatt hours {GWh}).

As part of the analysis, the impacts of changes in structural and electricity intensity were calculated for the Service and Industrial sectors. In these cases, a model was constructed to calculate how electricity use would have changed had one variable (i.e. electricity use per square metre of floor area) been held constant. The difference between actual historic use and the value calculated represents the impact of the change in structure or intensity.

In the discussion of electricity demand patterns, very little data for Ontario was available in the public domain. Load shape data published by the Independent Electricity System Operator (IESO) on its website (www.iemo.com) was used to construct an illustrative demand model. This load data is from 1998, and is assumed to have been collected by Ontario Hydro. The IESO was contacted to obtain information on the data, but while staff were generous in their efforts to assist, they had little information on how the original data had been gathered.

The sector descriptions used for the load shape data did not match exactly to those used in the OEE energy data. Where the descriptions differed, judgment was used in selecting the most appropriate load shapes available to match the sub-sectors and end use definitions used by OEE.

The load shape data is published for typical weekdays and weekend days for each month. In most instances, the data had been normalized for a 1 MW load. In order to construct a model for the Ontario system as a whole, the annual energy associated with each load shape was calculated. The energy use represented by the load shape was then compared to total Ontario energy use for the selected load in order to calculate the percentage of total Ontario load represented by the load shape. Each load shape was then weighted by its proportion of total Ontario electricity use to calculate a load shape for each sub-sector or end use for a typical weekday in January or July.

Once a peak day load shape had been created, the peak hour for that load shape was determined. The percentage contributions of each load shape (i.e. sub-sector or end use) to the peak demand were then calculated. To simplify presentation, any sub-sectors which contributed less than 5 percent of the total peak were aggregated into Other Industry or Other Services.

This model is intended to provide only a general illustration of demand contributions by economic sector and end use. Two caveats should be borne in mind:

- There is limited information regarding the underlying load shape data used in the model. It would be useful to have information that is more current and to know that the sample size was sufficient to ensure that it reasonably represents Ontario loads.

- The data is for a "typical" weekday. Obviously the critical loads which drive the summer peak, and to a lesser extent the winter peak, behave differently on very hot or cold days than on typical days. For this reason, the model is assumed to under-represent the contribution of Residential and Service sector cooling loads.

It should be noted that there is a great deal of hourly load information available in Ontario. Most Local Distribution Companies have had hourly interval meters installed on large customers for well over 10 years and many have extended the use of interval metering down to customers of 2-300 kW per month in recent years. Utilities are also in the process of collecting load shape and consumption data on different customer classes and loads as part of the process of reviewing

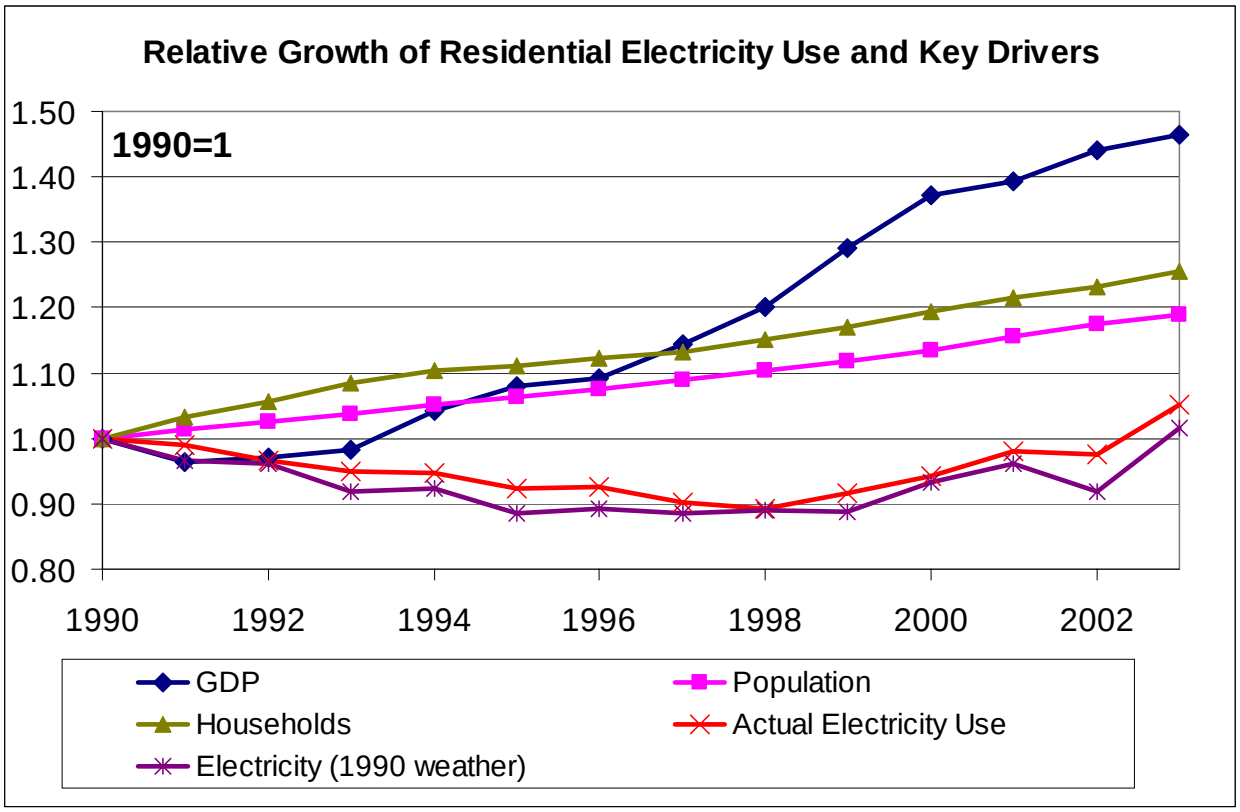
Residential Sector

The residential sector accounted for 33.8 percent of electricity used in 1990, and fell slightly to 32.9 percent by 2003; the relative growth rates of some of the key drivers are shown in Figure 8. While GDP would not be expected to be strongly correlated with growth in residential electricity use, it is shown as a point of reference for the observed decoupling of total electricity use from total economic activity. More importantly, while population and households were up 19 percent and 25 percent, respectively, and total residential floor area was up 32 percent (a trend toward bigger houses continued throughout the period), residential electricity actually declined from 1990-1998, and by 2003 had only just regained its 1990 level of about 47,000 GW.hours. The average electricity use per household declined fully 16 percent during this period, as compared with a decline in per household energy use (including all fuels) of 6.1 percent.

Figure 9 shows the distribution of residential electricity use by end use in 2003. The figure is an illustration of the share of total residential electricity use, but the average electricity use per household and the corresponding breakdown by end use will vary depending on whether electricity is used for space heating and/or water heating. The sensitivity of residential electricity use to both the size of the major end use categories and the market share held by electricity is further illustrated in Figure 10. While the average household in Ontario consumes a little over 10,000 kW.hours per year, not too many households consume the average. Households that use electricity only for lighting, appliances and air conditioning use about 8,000 kW.hour per year on average. Electric water heating adds another 5,000 kW.hour to this total, but only about 33% of Ontario households use electricity for water heating. Electric space heating will add nearly 17,000 kW.hours to household electricity use but only about 15% of Ontario households heat

with electricity. Relatively small changes in electricity's share of the space and water heating market have relatively large impacts on the total residential electricity use in the province.

Figure 8



Over the 1990-2003 period, the relative shares of end uses in the makeup of residential electricity changed as illustrated in Figure 11. Energy use for water heating, refrigerators and freezers declined, however, increases in air conditioning, home electronics (other appliances) and lighting, more than offset these gains. Efficiency gains in major appliances (refrigerator use declined 33 percent, freezer use declined 44 percent, dishwasher use decreased 7 percent and clothes washers by 4 percent) amounted to approximately 2.9 GW.h over the period. By contrast, consumption by Other Appliances increased by about 2.7 GWh as shown in Figure 11.

Electricity use for space heating grew by 4.9 percent over the period, although its share of the heating market declined from 12.8 percent to 11.3 percent. Part of this decline in market share reflects the increased use of natural gas heating in new construction. The actual number of homes using electric heat, including heat pumps and dual-fuel heating systems, increased by 13 percent over the period. Most of this increase was for heat pump systems, often in conjunction with gas heating. *The stock of homes with baseboard heating declined by 5 percent over the period, leaving approximately 666,000 homes with that type of system by 2003.*

Figure 9. Ontario Residential Electricity End Use Shares, 2003

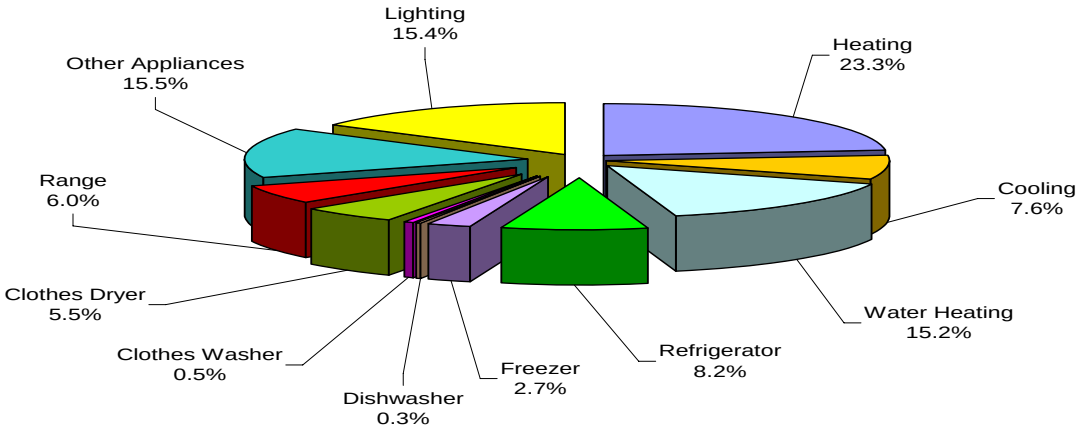
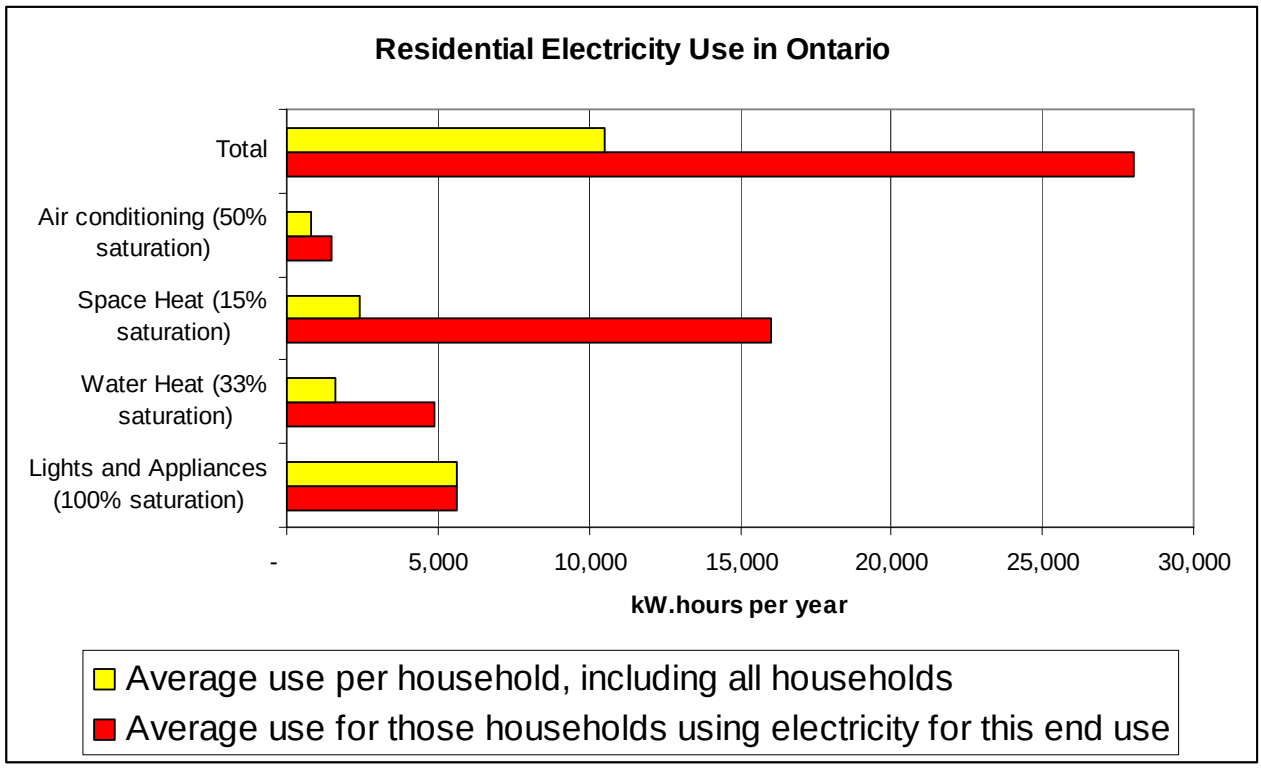
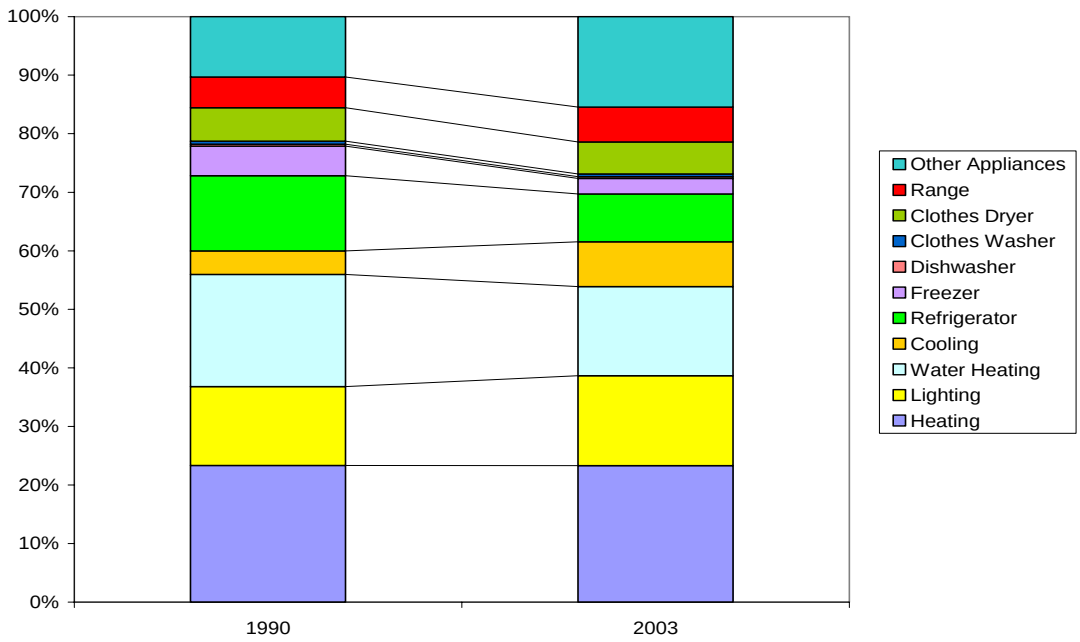


Figure 10



Electric water heating energy use decreased by 16.4 percent from 1990 to 2003. As a result, the share of residential electricity used for water heating declined from 19 percent to 15 percent over the period. Electricity's share of the domestic water heating market fell from 33 percent to 22 percent; the number of homes with electric water heating fell from a high of 1.7 million homes in 1991 to a low of 1.48 million in 1991, but then started to increase again. *By 2003, there were 1.61 million households with electric water heating in the province.*

Figure 11 Residential Electricity Use by End Use



Cooling energy use increased by over 100 percent from 1990 to 2003, reflecting the increased prevalence of central air conditioning. Over the period, energy use by central air systems increased by 121 percent while use by room air conditioners increased by under 20 percent. Part of this increase in consumption reflects differences in the weather. Cooling degree days were approximately 20 percent higher in 2003 than in 1990. If the summer of 2003 had been comparable to 1990, the increase in air conditioning electricity use would have been closer to 70 percent. While air conditioning energy use represents only 7.6 percent of annual electricity use in the residential sector, it has a disproportionate impact in terms of demand.

Among appliance end uses, new major appliances became substantially more efficient. As the stock of appliances was replaced, this was reflected in decreased average electricity use (i.e. refrigerators on average used 16.4 percent less over the period). There was essentially no change in the average number of refrigerators or freezers per household over the period. Table 1 shows how the average electricity use of new appliances changed between 1990 and 2001, and combined with the saturation rates shown in Table 2, the change in actual electricity use per household and per appliance over the 1990-2003 period is shown in Table 3.

Table 1.

Electricity Use by New Major Appliances, Efficiency Improvements, 1990 and 2001

	1990	2001
Refrigerators	950	559
Freezers	714	384
Dishwashers	1025	634
Electric Ranges	772	762
Clothes Washers	1218	810
Clothes Dryers	1102	916

Source: Energy Consumption of Major Household Appliances Shipped in Canada; Trends for 1990-2001; Natural Resources Canada, December 2003

Table 2.

Appliance Saturations and Replacement Rates

Appliance Type	1993 Stock ('000)	% of all Households	1994/95 Purchases ('000)	% of all Households
Refrigerators	10,313	99.6%	1,156	10.2%
Range	10,359	1.0%	950	8.4%
Dishwasher	4,566	44.1%	804	7.1%
Freezer	6,226	60.1%	505	4.4%
Washing Machine	8,020	77.4%	1,057	9.3%
Clothes Dryer	7,645	73.8%	882	7.8%
Central Air Conditioning	1,579	15.2%	210	1.8%
Window Air Conditioner	1,134	15.2%	166	1.5%

Source: The Household Equipment of Canadians, Features of the 1993 Stock and the 1994 & 1995 Purchases, Analysis Report, Natural Resources Canada, March 1997

Table 3

Changes in Ontario Residential Appliance Efficiency

	1990	2003	Absolute Change	Total % Change	% Change per Year
Average Use per Household *(all households)*					
Refrigerator	1,603	852	(751)	-88.1%	-4.7%
Freezer	630	278	(351)	-126.2%	-6.1%
Dishwasher	42	31	(11)	-35.2%	-2.3%
Clothes Washer	64	49	(15)	-31.2%	-2.1%
Clothes Dryer	780	654	(126)	-19.2%	-1.3%
Range	723	715	(8)	-1.1%	-0.1%
Other Appliances	1,285	1,614	328	20.4%	1.8%
Use per Appliance *(for actual stock)*					
Refrigerator	1,301	676	(625)	-92.4%	-4.9%
Freezer	1,102	519	(583)	-112.5%	-5.6%
Dishwasher	107	61	(46)	-76.2%	-4.3%
Clothes Washer	91	64	(26)	-41.2%	-2.6%
Clothes Dryer	1,132	836	(295)	-35.3%	-2.3%
Range	731	717	(14)	-2.0%	-0.2%
Other Appliances	188	177	(12)	-6.6%	-0.5%

Notes: Some homes have multiple major appliances. Use per Household shows average use for all households including those with no appliance or those with multiple app Use per Appliance shows average use based on the actual stock of appliances.

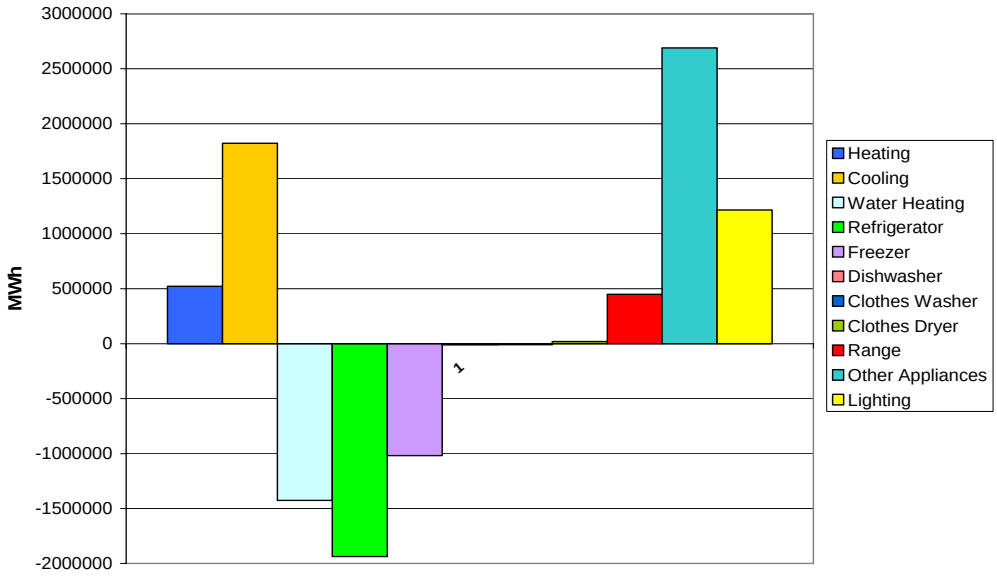
Electricity use by "Other" appliances, such as home electronics, increased by 57 percent over the period 1990 to 2003. Lighting use increased by almost 20 percent. There is limited information available on the appliances included in the "other appliance" category within the OEE database. *Given the increasing load associated with these appliances, further investigation of these loads, their efficiency and saturations would appear warranted.*

The total housing stock in Ontario increased by 25.2 percent or 958,000 units between 1990 and 2003 growing at 1.7 percent per year. The most rapid growth occurred in Single Attached homes (47 percent) followed by Single Detached (27.9) and Apartments (12.5 percent). The number of mobile homes declined over the period by almost 15 percent. By the end of the period, the housing stock was comprised of 57 percent single detached homes, 18 percent apartments, and 14 percent single attached homes. The more rapid growth in houses vs. apartments may account for the increase in average floor area per home.

The data available from the OEE provides limited information on energy use by heating fuel type (i.e. electricity vs. gas or oil) by building type or vintage. As a result, it was not possible to examine trends in energy use between building types.

Usage per household (intensity) fell from 12,474 kWh annually in 1990 to 10,445 kWh per year in 2003 (870 kWh per month). Figure 12 shows how changes by end use contributed to the overall change in electricity use for the sector between 1990 and 2003.

Figure 12 Changes in Residential Electricity Use – 1990 to 2003



Commercial & Institutional Sector

The Commercial and Institutional (Service) sector accounted for 36.6 percent of total electricity used in 2003. This represents an increase in share from 1990 when it represented 30.4 percent of the total. Electricity use in the Services sector grew more rapidly than for any other sector. From 1990 to 2003, electricity use increased 30.1 percent or 2.0 percent per year. Total floor area for the sector grew 24.9 percent reflecting a modest *increase* in electricity intensity.

The relative growth rates of commercial sector electricity and some of the key drivers are shown in Figure 13. Services sector GDP now dominates Ontario's total GDP and tracked it closely over the 1990-2003 period. Building floor area tends to grow much slower than output, and commercial building electricity use tracks building floor area fairly closely.

Figure 14 shows the distribution of commercial sector electricity use by sub-sector for 2003. Over half of the electricity used by the sector went to Offices (54 percent) with Accommodation and Food (16 percent) and the Retail sector (11 percent) representing the next largest users. Electricity use grew more rapidly than floor area in several sub-sectors between 1990 and 2003, representing an increase in electricity intensity for those building types.

For the Services sector as a whole, energy intensity increased slightly, from 1.9 to 2.2 GJ per m2, between 1990 and 2003. Electricity intensity also increased slightly, from 250 to 260 kWh per square metre over the period. Figure 15 compares the electricity intensity, in kWh per square metre, for each sub-sector for 1990 and 2003. While the Accommodation and Food industry represents less than 5 percent of total floor area, its higher energy intensity results in it representing over 15 percent of total electricity use.

Table 4

Figure 13

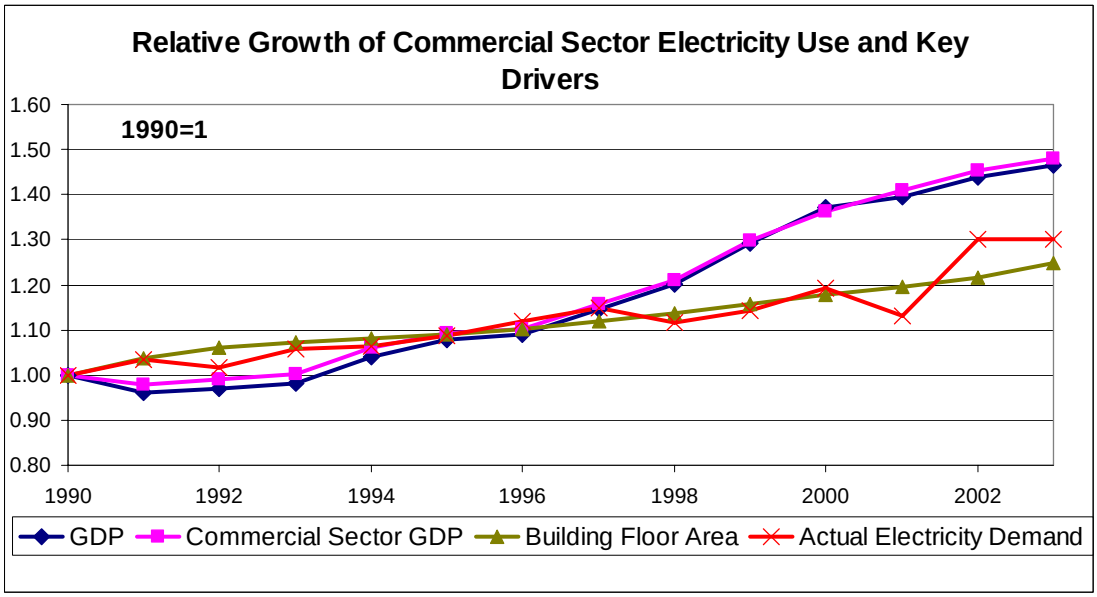


Figure 14 2003 Service Sector Electricity Use by Sub-Sector

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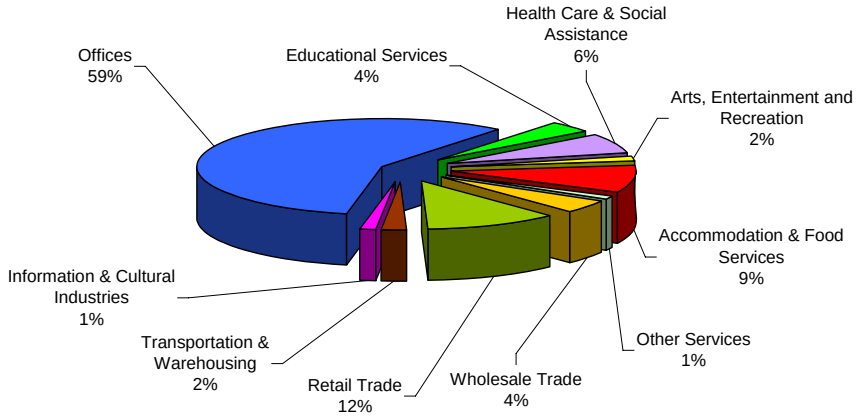

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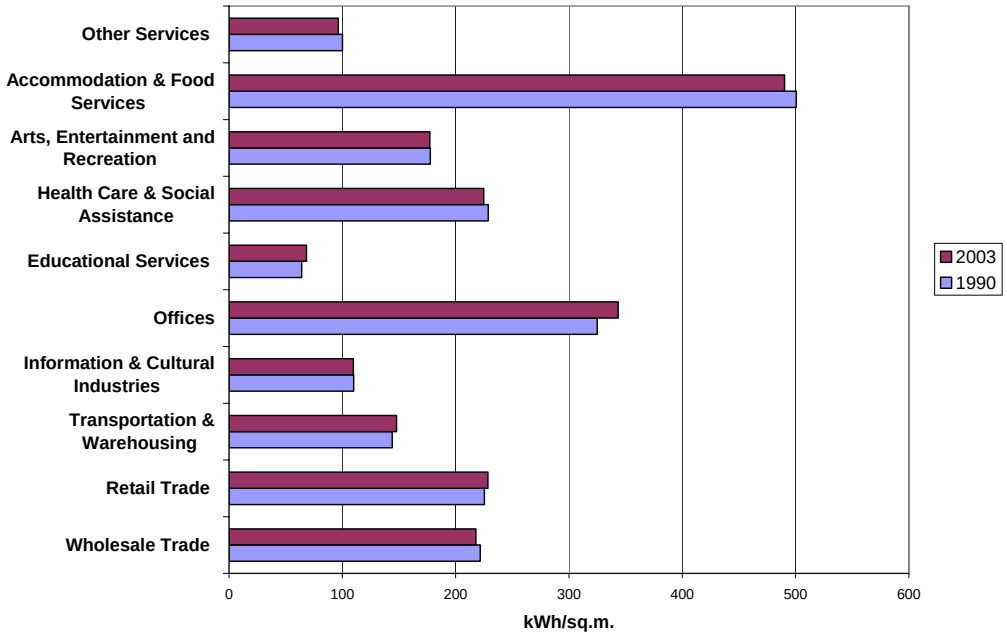
Table 4

Growth in Electricity Use vs. Floor Area by Sub-Sector

	Growth in Electricity Use	Growth in Floor Area
Wholesale Trade	1.2%	3.0%
Retail Trade	8.8%	7.3%
Transportation & Warehousing	1.5%	-1.1%
Information & Cultural Industries	0.0%	43.8%
Offices	41.7%	34.1%
Education	38.7%	29.8%
Health Care & Social Assistance	26.3%	28.5%
Arts, Entertainment & Recreation	49.2%	49.4%
Accommodation & Food Services	21.7%	24.2%
Other Services	10.0%	14.1%

Figure 15 Energy Intensity for Services Sector



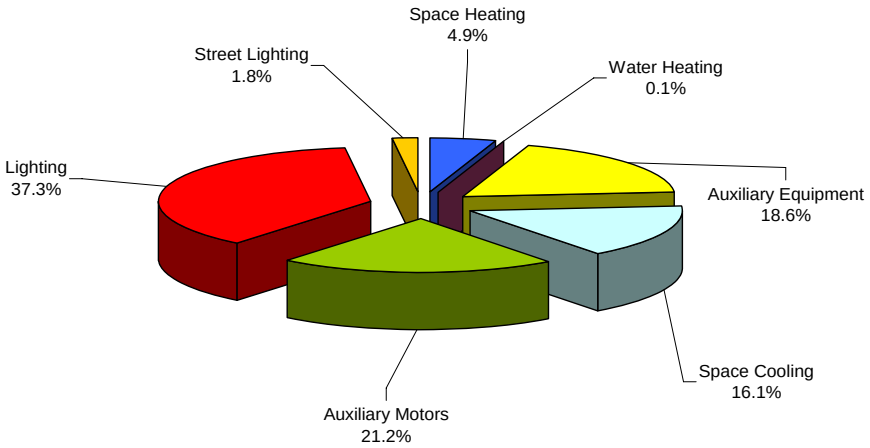
Electricity intensity increased in the Offices (5.6 percent), Education (6.8 percent), Transportation & Warehousing (2.7 percent) and the Retail sector (1.4 percent) between 1990 and 2003; intensities fell in all the other sub-sectors.

Table 5

Electricity Intensity by Sub-Sector (kWh/sq. m.)

	1990	2003
Wholesale Trade	222	218
Retail Trade	225	229
Transportation & Warehousing	144	148
Information & Cultural Industries	110	110
Offices	325	343
Education	64	68
Health Care & Social Assistance	229	225
Arts, Entertainment & Recreation	178	177
Accommodation & Food Services	501	490
Other Services	100	96

Figure 16 2003 Service Sector Electricity Use by End Use



Lighting represents the largest single end use within the Service sector, accounting for over 37 percent of electricity use. Auxiliary motors (24 percent), auxiliary equipment (21 percent) and cooling (14 percent) were the next largest end uses (see Figure 16).

Electric space heating, which represented just 2.3 percent of electricity use in the sector in 1990, grew by 185 percent (over 8 percent per year) over the period. As a result, its share of total electricity use more than doubled to 4.9 percent.

Water heating electricity use, by contrast, fell by 80 percent. By the end of the period, its share of total electricity use had fallen to just 0.1 percent.

Electricity use for air conditioning rose by 52 percent reflecting increasing its share of total electricity use, as in the residential sector. Over the period, however, natural gas began to capture an increased share of the cooling market. In 1990, electricity supplied over 96 percent of cooling for the service sector. By 2003, approximately 15.5 percent of cooling was provided by natural gas.

Lighting energy use increased by 33 percent over the period being reviewed, while total floor area for the sector increased by 24.9 percent. *This implies a slight increase in lighting energy use per square meter*. In 2000, the OEE carried out a Survey of Commercial & Institutional Building Energy Use. They reported that in Ontario, 43 percent of buildings had installed energy efficient ballasts and that 31 percent used energy efficient lamps (see Table 6). Given that approximately 70 percent of commercial/institutional lighting is fluorescent and that new T8 lamps are at least 25 percent more efficient than traditional T12 lamps and ballasts, the lack of improvement in lighting efficiency reflected in the OEE database is therefore somewhat surprising.

Table 6

Reported Lighting Conservation Features for Ontario – 2000 Survey

Conservation Measure	% of Buildings Reporting Measure
Reflectors	23.7%
Energy Efficient Ballasts	42.6%
Daylight Controls	13.9%
Occupancy Sensors	9.0%
Time Clocks	26.3%
Manual Dimmer Switches	23.0%
Energy Efficient Lamps	31.1%
Other	10.0%

Source: Survey 2000, Commercial & Institutional Building Energy Use, Detailed Statistical Report, Natural Resources Canada, December 2002.

Table 7 shows lighting intensities in kWh per square metre for the Commercial & Institutional sub-sectors. As the table shows, lighting intensities increased in all of the sub-sectors, apparently in spite of improved efficiency lighting systems.

Table 7
Lighting Intensity by Sub-Sector (kWh/sq.m.)

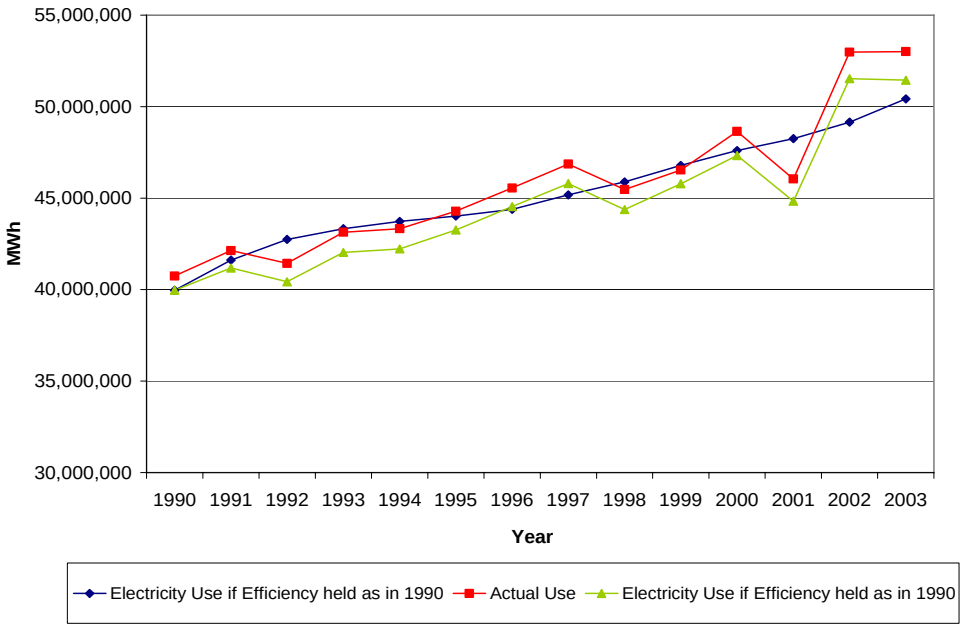
	1990	2003
Wholesale Trade	71	75
Retail Trade	71	73
Transportation & Warehousing	75	77
Information & Cultural Industries	40	41
Offices	134	142
Educational Services	27	28
Health Care & Social Assistance	86	88
Arts, Entertainment and Recreation	64	65
Accommodation & Food Services	96	99
Other Services	36	37

It should be noted that changes in lighting intensity also impact space cooling loads. As a rule of thumb, every watt of lighting reduction is normally assumed to reduce cooling loads by 0.25 watts.

Street lighting electricity use increased by 15.2 percent between 1990 and 2003. While no activity measure is readily available for street lighting, the number of households increased by 25 percent. Assuming that the number of streetlights should increase roughly in proportion to the number of households, this implies an increase in lighting efficiency for street lighting.

Figure 17

Service Sector Electricity Use – Structural vs. Efficiency Impact



In order to measure the relative contributions structural change versus changes in energy intensity, two analyses were carried out to calculate 2003 electricity use: 1) if the relative share of floor area in 1990 (i.e. structure) was held constant, and 2) if 1990 electricity intensities were held constant. The outcomes of these analyses are displayed in Figure 17.

Actual electricity use by the sector increased by 30.1 percent between 1990 and 2003. Had the sub-sectoral shares of floor area remained fixed at 1990 levels, electricity use by the Service sector would have increased by 28.8 percent over the same period. Had electricity intensity remained unchanged at 1990 levels, electricity use would have grown by 26.2 percent by 2003. In energy terms, 2003 usage would have been 1,560 GWh lower had 1990 shares of floor area been maintained, or 2,589 GWh lower if electricity intensity had not increased.

Figure 18 and Figure 19 show how the changes in end use and sub-sector growth contributed to total Service sector electricity use.

Figure 18 Contributions to Service Sector Electricity Growth by End Use – 1990 to 2003

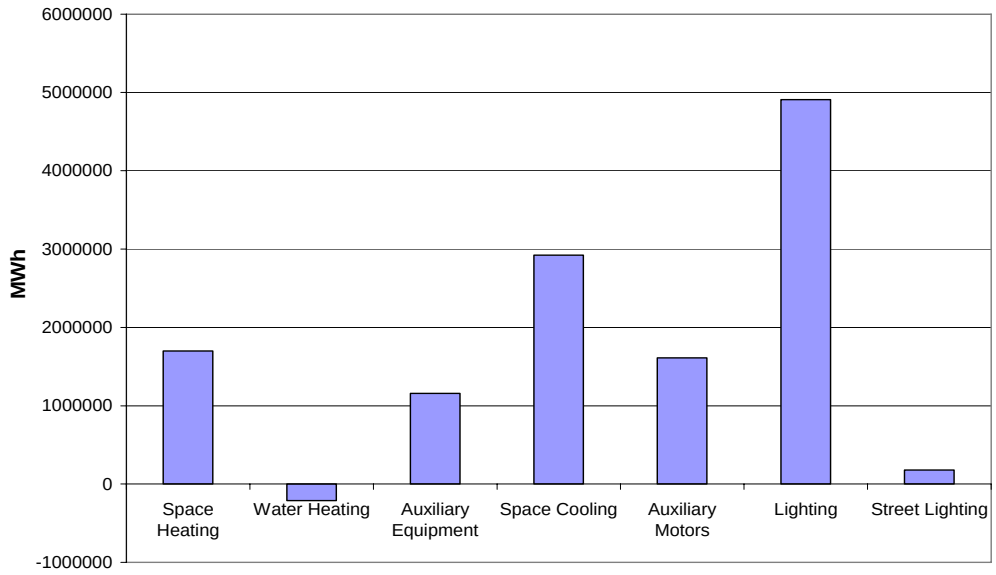
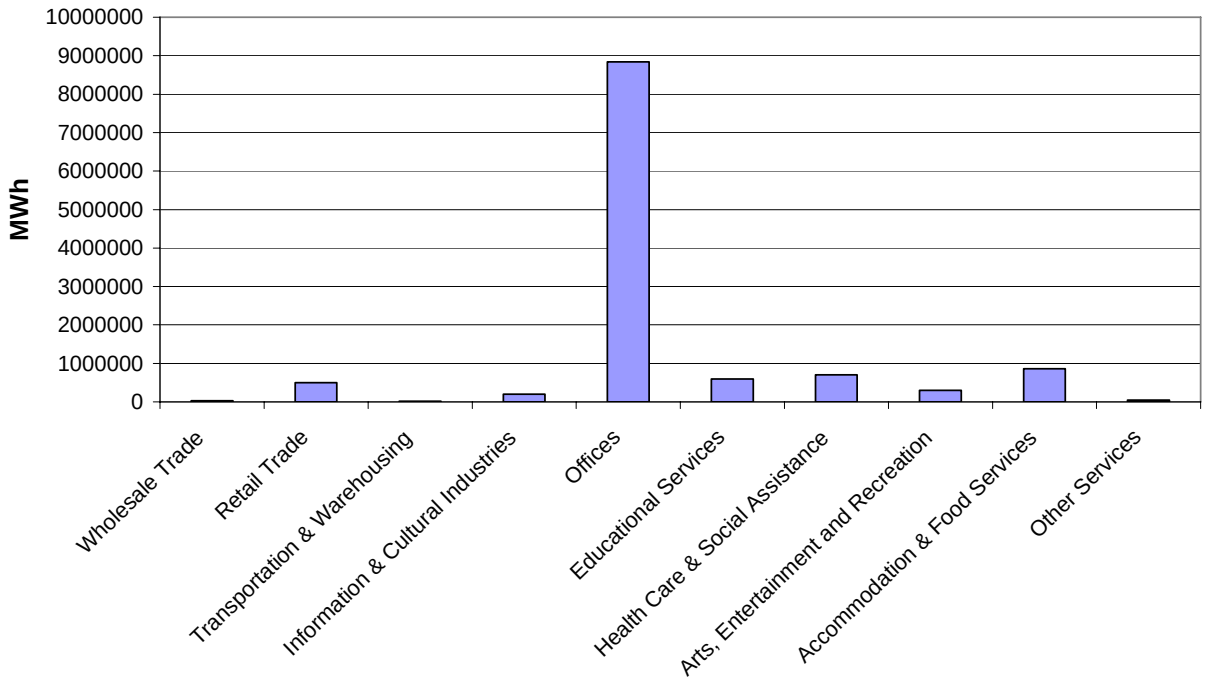


Figure 19 Contributions to Service Sector Electricity Growth by Sub-Sector – 1990 to 2003



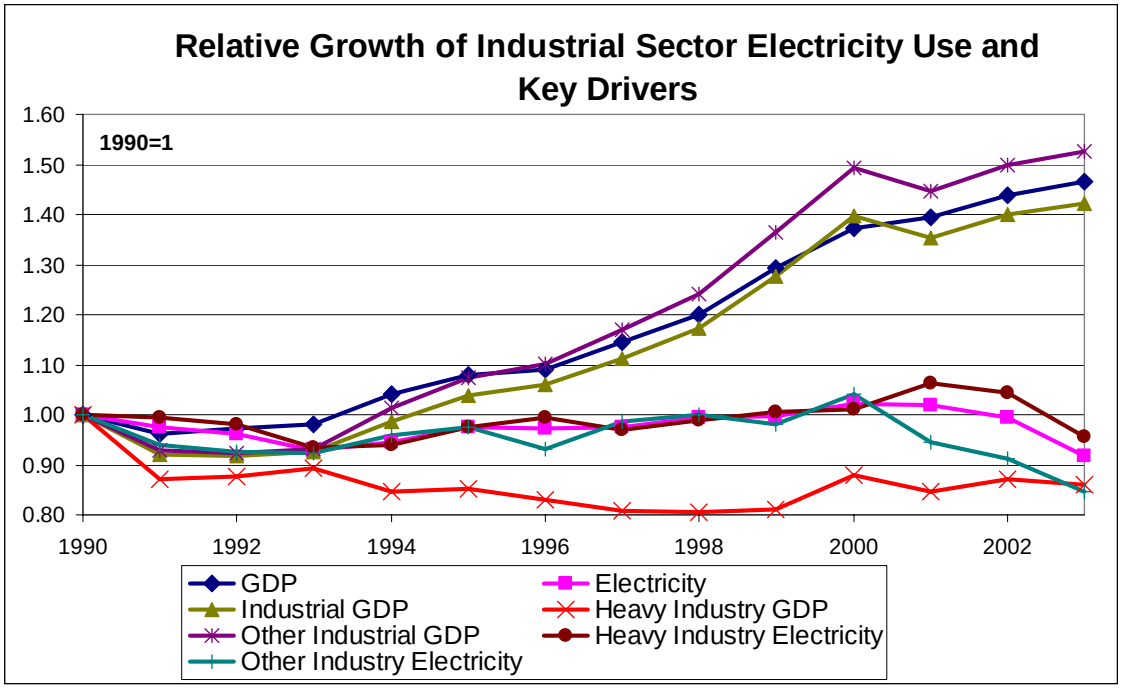
Industrial Sector (including Transportation and Agriculture)

The industrial sector consumed 28.6 percent of all electricity used in Ontario in 2003. Industrial electricity use declined by 9.3 percent between 1990 and 2003. Agricultural electrical use, which accounted for 1.69 percent of total electricity grew by 12.4 percent over the period, while transportation use (0.3 percent of total) declined by 1.8 percent.

Industrial electricity use and some of its key drivers are illustrated in Figure 20. Overall, industrial GDP has tracked total GDP for the province, but there is an important difference here between "heavy industry" and other industry.[1] Total output from the electricity intensive primary industries declined throughout the period, while output from the other, much less electricity intensive industries grew slightly faster than the average economic growth rate.

[1] Including the Heavy Industry grouping in thief analysis are Pulp and Paper, Iron and Steel, Industrial Chemicals, Petroleum Refining, Mining and Primary Metals Smelting and Cement.

Figure 20



The electricity use per dollar of in the primary industries is an order of magnitude greater than for the secondary manufacturing industries, so the divergent growth rates of these two parts of Ontario's industrial economy has and continues to have a profound impact on industrial electricity demand. Further, *within* the secondary manufacturing industries there has been a marked increase in the value added produced per kilowatt-hour consumed. The net result of these factors has been stable or declining electricity consumption in Ontario's industrial sector. While industrial electricity use declined, the economic output of the sector grew by 42 percent. As a result, electricity intensity, measured in MWh per 1997$ GDP, decreased 26 percent.

Figure 21. Electricity per Dollar of Output for Selected Industries

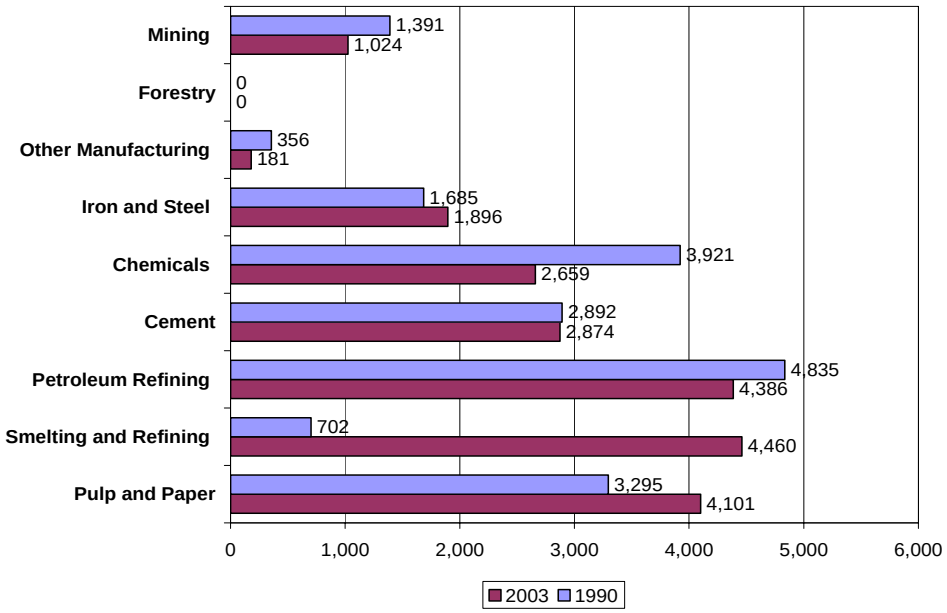


Figure 22. 2003 Industrial Electricity Use

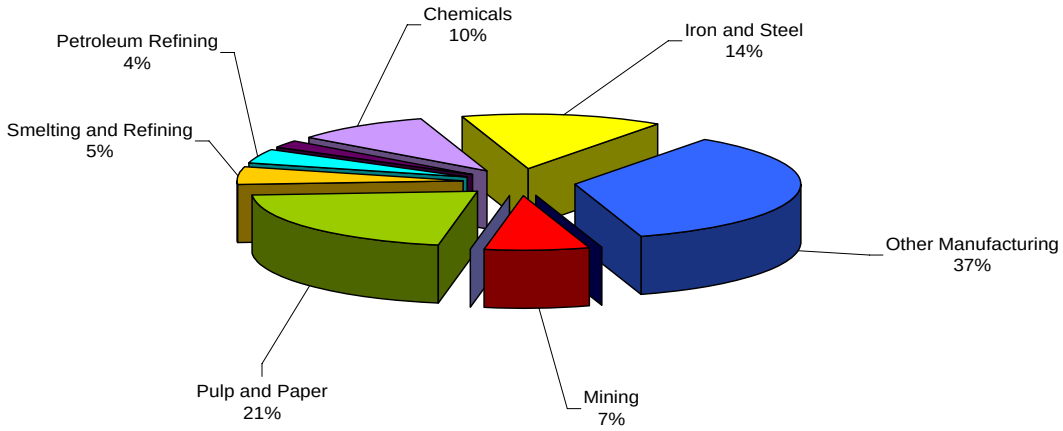


Figure 22 shows how electricity was used by sub-sector in 2003, while Figure 23 shows the relative contributions to the change in electricity use by industrial sub-sector.

Figure 23

Contributions to Change in Industrial Electricity Use - 1990 to 2003

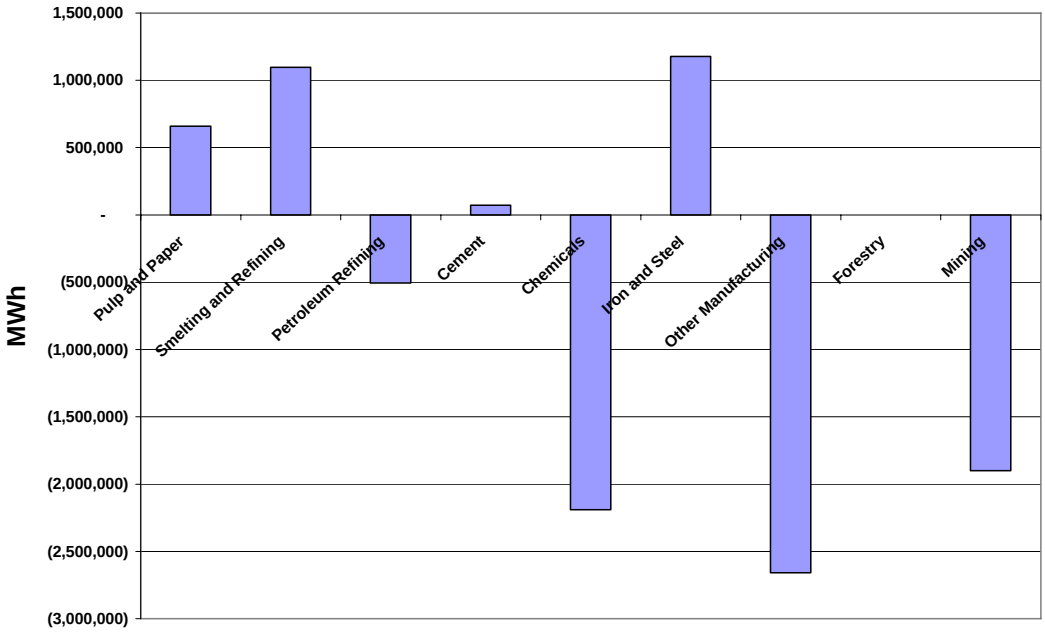
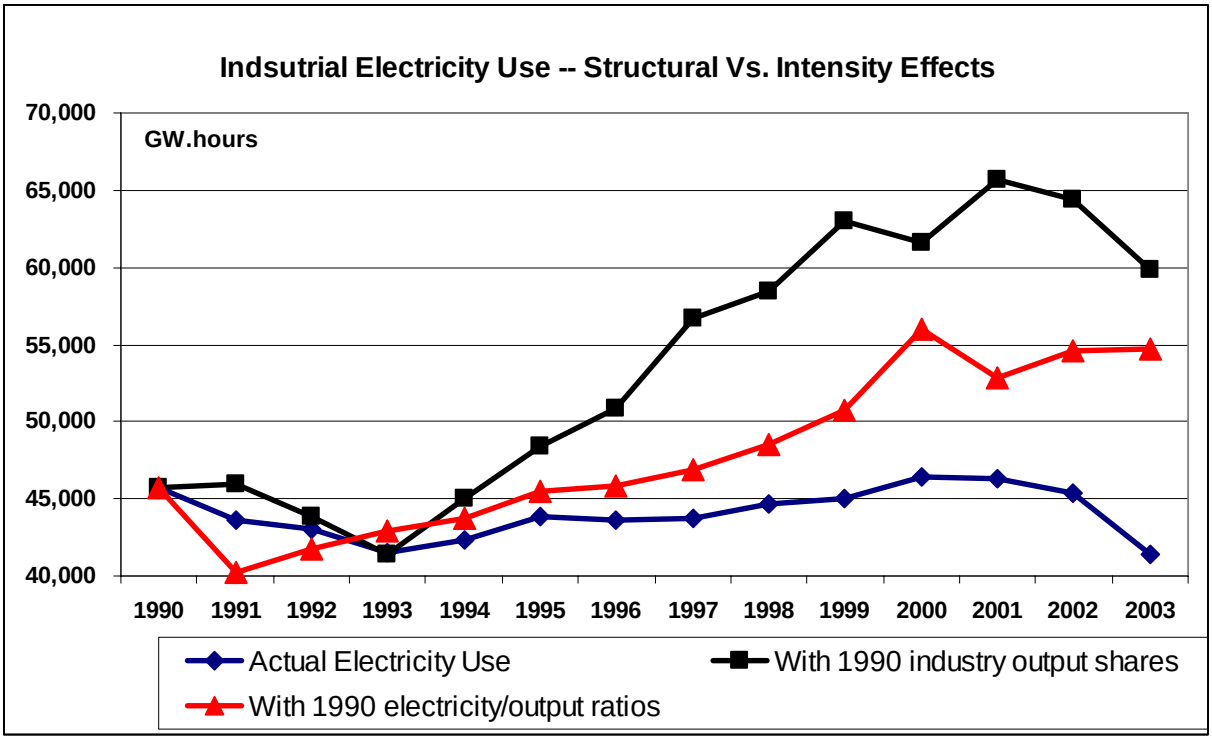


Table 8. Comparison of Growth in Power Consumption and GDP by Sub-Sector

	Growth in Electricity Use	Growth in GDP 1997 $
Construction	0%	17%
Pulp & Paper	8%	-13%
Smelting & Refining	98%	-69%
Petroleum Refining	-23%	-15%
Cement	9%	9%
Chemicals	-35%	-4%
Iron & Steel	25%	11%
Other Manufacturing	-15%	67%
Forestry	0%	11%
Mining	-38%	-16%

In order to measure the relative contributions structural change versus changes in energy intensity, two analyses were carried out to calculate 2003 electricity use: 1) if 1990 structure was held constant, and 2) if 1990 electricity intensities were held constant. The results are summarized in Figure 24.

Figure 24



Actual electricity use by the sector decreased by 9.3 percent between 1990 and 2003. Had the sub-sectoral shares of GDP remained fixed at 1990 levels, industrial electricity use would have increased by 31 percent over the same period. Had electricity intensity remained unchanged at 1990 levels, electricity use would have been 19.8 percent higher in 2003. In energy terms, 2003 usage would have been 18,418 GWh higher had industry structure not changed, or 13,308 GWh higher had electricity intensity not decreased.

4. Demand Implications

Ontario's electricity system has traditionally peaked during the winter months, either during the Christmas period as a result of seasonal outdoor lighting, or in the coldest month, due to electric heating requirements. In 1998, for the first time, the system peaked during the summer. Since that time, the annual peak has occurred during hot summer weather in every year except 2000. The IESO reports that while winter peak demand grew by 0.7 percent per annum between 1987 and 2004, the summer peak has grown by 1.3 percent. Table 9 shows a comparison of the contribution by sector to peak demand versus energy use.

Table 9. Comparison of Energy and Demand Contributions by Sector (1999 data)

	Contribution in % to Peak Demand	Percentage of Total Energy Use
Industrial	33.6	33.1
Commercial	38.3	34.2
Residential	26.1	30.5
Agricultural	1.4	1.9
Transportation	0.6	0.3

Notes: *Demand information from the IESO web site.*
Energy information based on OEE database.

While this data relates to the period when the system had just become summer peaking, it does show that the Residential sector makes a disproportionate contribution to peak demand. The higher average load factors in the industrial and commercial sectors result in their contributions to the peak being relatively lower than their contributions to energy use.

Space cooling energy use has increased rapidly in both the Residential and Services sector over the past 13 years. Air conditioning loads have a very low annual load factor and a very high coincidence with the system peak. As the saturation of residential air conditioning has increased, the system has become much more weather sensitive. This has resulted in the Ontario electricity system moving from a winter to a summer peak.

In order to gain a clearer picture of the drivers of the system peak, a model of Ontario electrical demand was constructed. Information on representative load shapes for industrial and Commercial/Institutional sub-sectors, as well as residential end uses was obtained from the IESO (Figure 25 to Figure 28).

These load shapes were then weighted based on 2003 electricity use derived from the OEE. The result provides an approximation of the contributions of the various sectors and end uses to a typical day load shape. It should be noted that the load shapes, particularly those for the residential end uses, represent an average day. The weather sensitive loads, such as air conditioning and heating, would be expected to be more pronounced on hotter or colder days when the peak demand typically occurs. There is also little information available on how the load patterns were gathered (i.e. how representative the sample may be). Despite these limitations, the resulting load shapes do provide a reasonable picture of the loads which drive the system peak.

Figure 29 and Figure 30 show a typical day load curve for an average weekday in July and January. **Error! Reference source not found.** below, shows the calculated contributions to a peak summer and winter day.

Figure 25

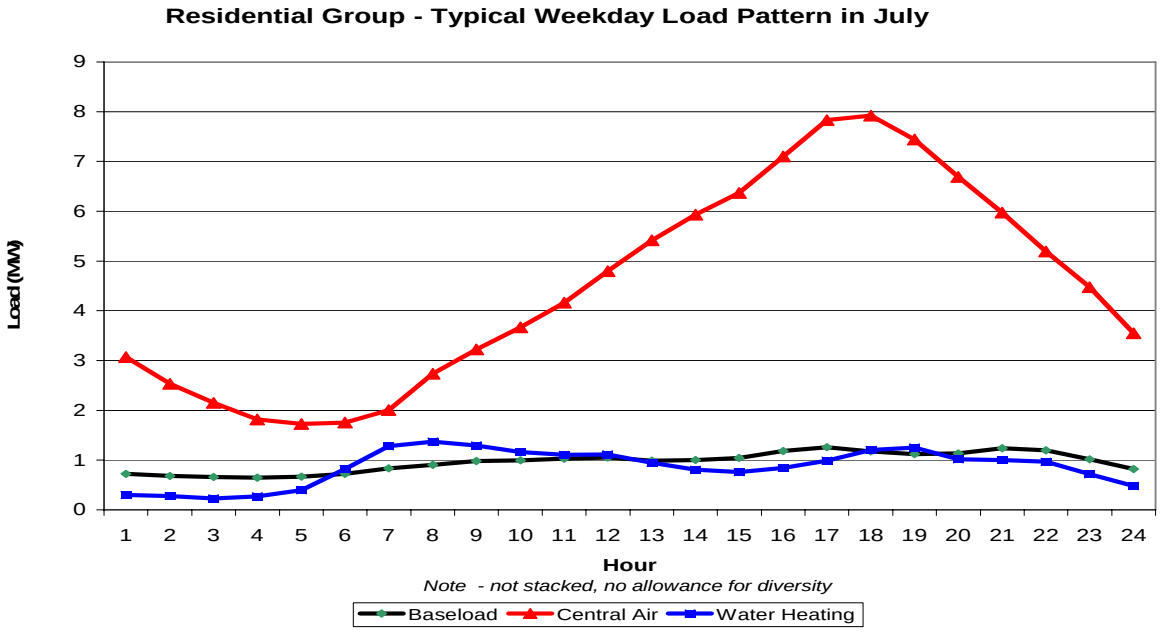


Figure 26

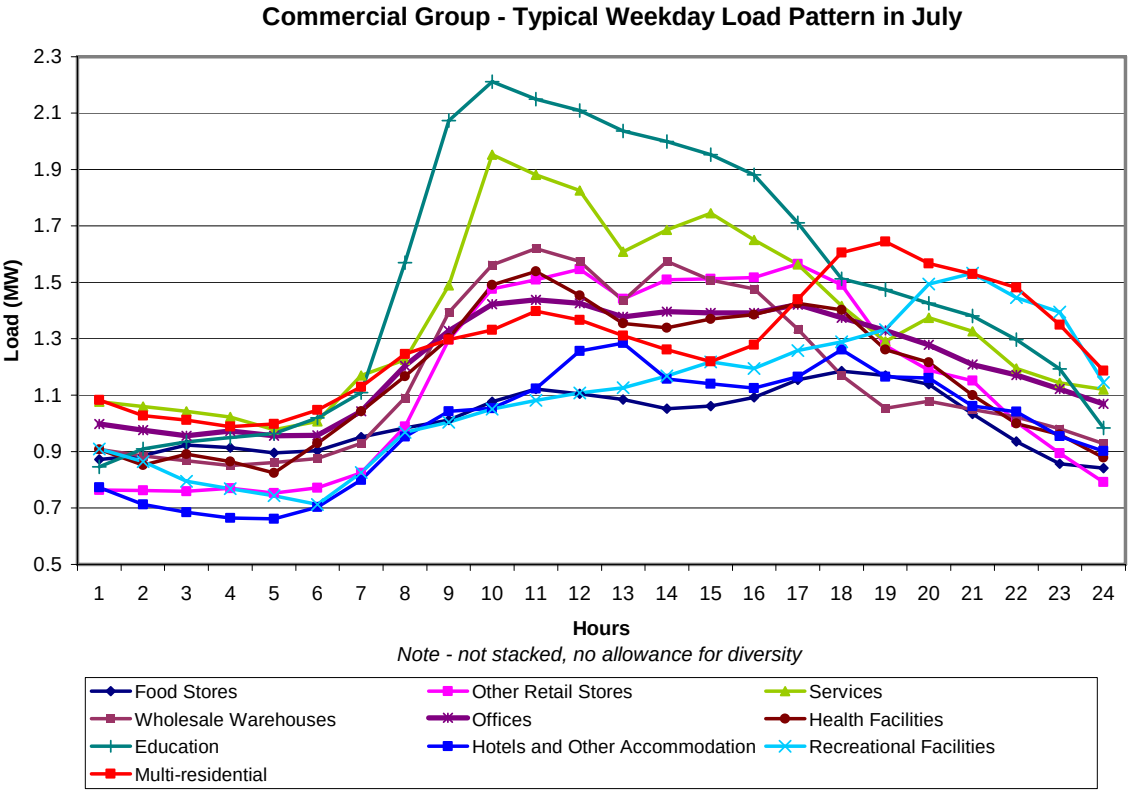
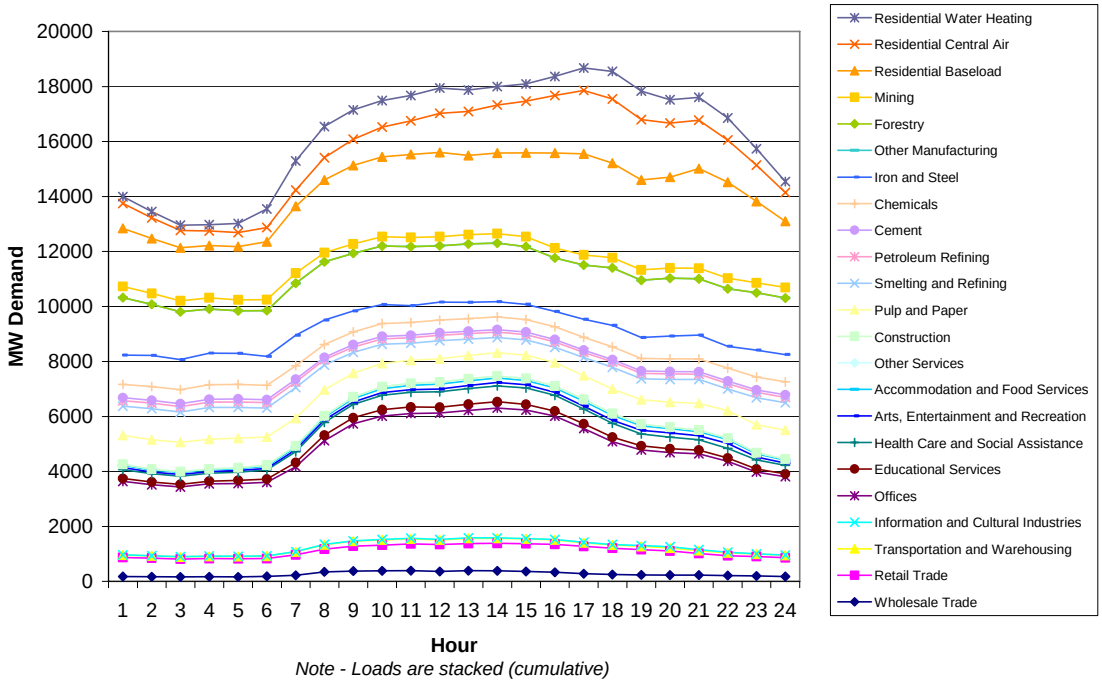


Figure 27 Small Industrial Group – Typical Weekday Load Pattern in July



Note - Loads are stacked (cumulative)

Figure 28 Direct Industrial Load Shapes for Average July Weekday

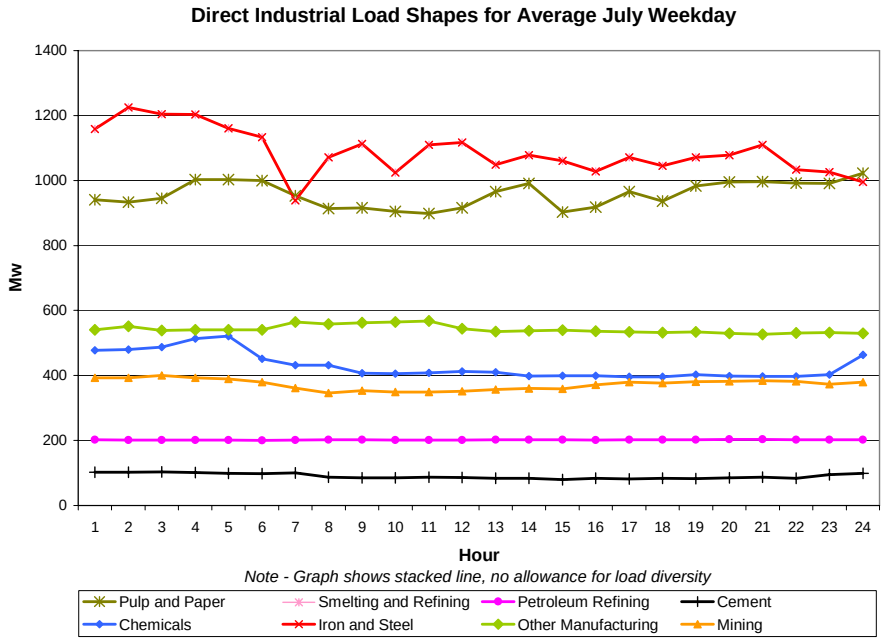


Figure 29

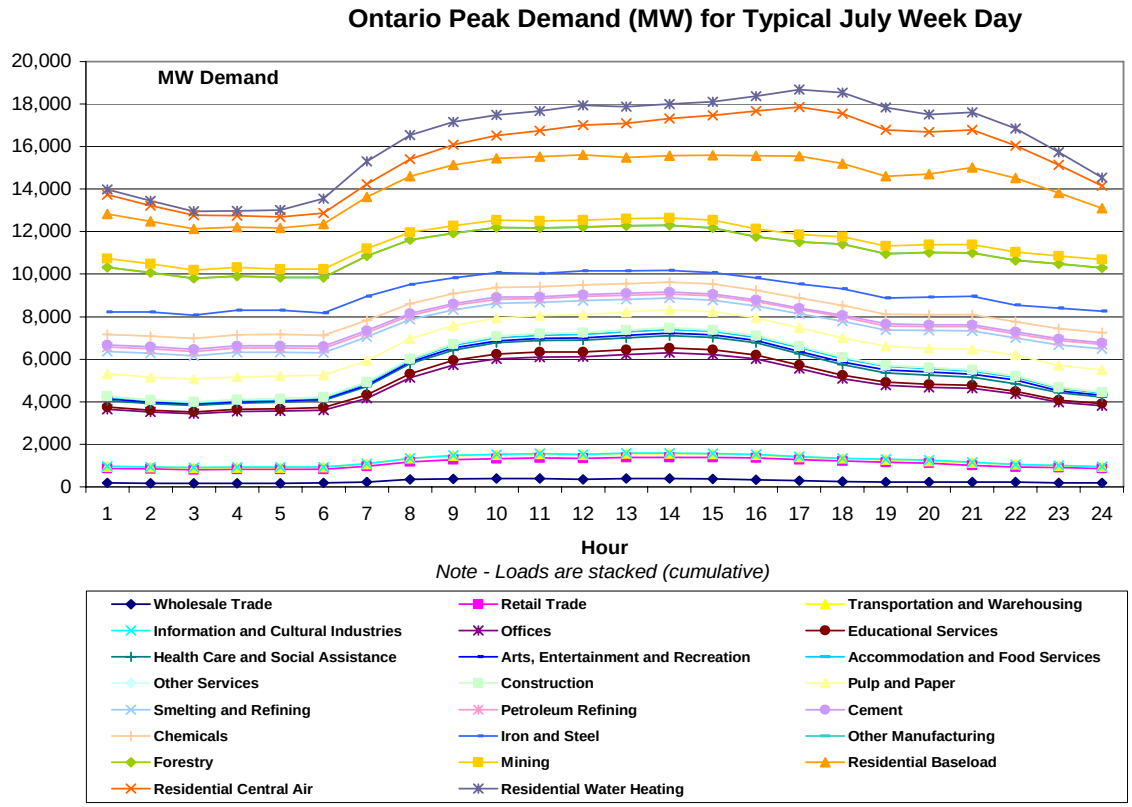


Figure 30

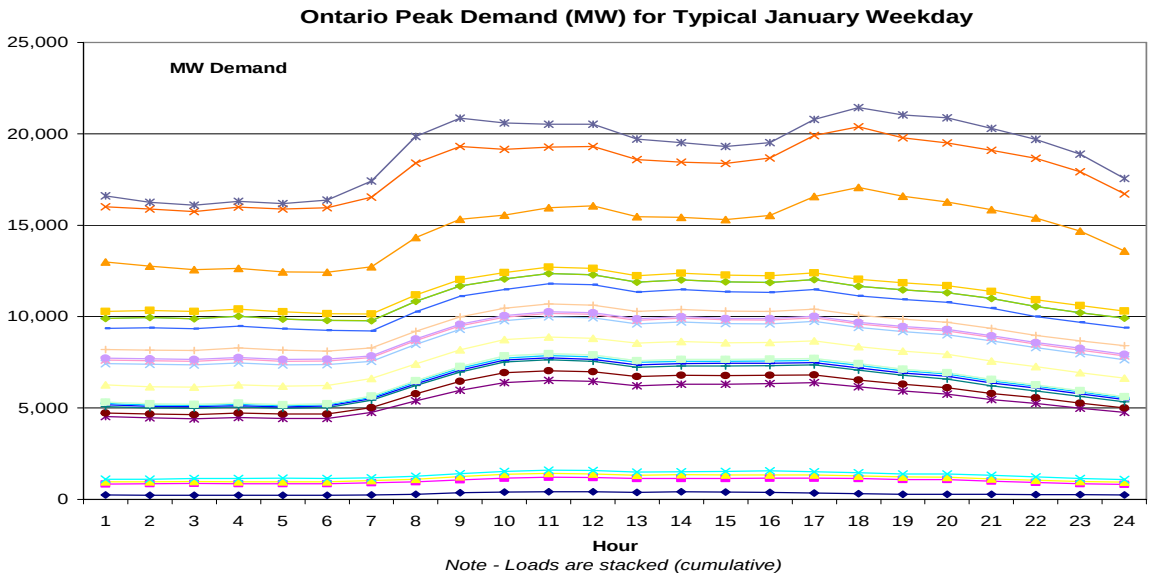


Table 10
2003 Ontario Electrical Demand Contributions to Peak Demand (as % of peak hour)

Typical Week Day for Sector/End Use	July	January
Offices	22.1%	22%
Retail Trade	5.3%	3.9%
All Other Services	8.0%	8.8%
Pulp and Paper	4.6%	4.4%
Smelting and Refining	3.5%	4.9%
Other Industries	5.9%	4.9%
Iron and Steel	3.5%	4.9%
Other Manufacturing	10.6%	2.5%
Residential Base load	19.7%	23.4%
Residential Central Air	12.3%	0%
Residential Water Heating	4.4%	4.9%
Residential Electric Heating	0%	15.4%
Total -	99.9%	99.9%

While there is very limited current load shape information publicly available a great deal of information is potentially available in Ontario. Local Distribution Companies (LDCs) in Ontario have had interval meters installed on many of their commercial and industrial customers for years. Current efforts to gather information for Cost Allocation studies and the implementation of Smart Meters should result in data being available on most classes and sizes of electricity consumers in Ontario.

5. Summary

Overall electricity use in Ontario grew by less than 1 percent per year (0.6 percent) between 1990 and 2003 for a total increase of 7.9 percent. In addition to being far lower than the historic growth rates prior to 1980s, this represented a growth rate well below that for either the economy or household formation. In effect, the electricity intensity of the Ontario economy decreased over the period as less electricity was used per household or per dollar of GDP.

Most of the growth in electricity use over the period under review took place in the Services sector. Residential electricity use increased by just over five percent at 0.4 percent per year. Industrial electricity use declined by 0.7 percent per year (9 percent in total) while output, as measured by real GDP increased by 2.7 percent per year (42 percent in total).

In the Residential sector, the electrical efficiency of major appliances increased significantly reducing their use (i.e. refrigerator use declined 33 percent). At the same time, the growing use of home electronics, computers and other small appliances resulted in an increase in the "Other Appliance" category increasing use by 57 percent. Residential lighting energy use also increased by 20 percent during the period. The reduction in electricity use by major appliances (2.9 GWh) effectively offset the increase in "Other Appliances" (2.7 GWh). Residential electric heating use increased by 6 percent during the period while electric water heating declined by 16 percent.

In the Services sector, the majority of growth in electricity use occurred in the Offices sector. Offices accounted for almost 40 percent of the floor area in the sector and over 53 percent of electricity use and saw the greatest rate of growth over the period. Electricity intensities and even lighting intensities (energy used per square metre) evidently increased over the period. Lighting represents the largest single end use within the Service sector, accounting for over 37 percent of electricity use, followed by auxiliary motors (24 percent), auxiliary equipment (21 percent) and cooling (14 percent). As in the Residential sector, space cooling grew rapidly over the period increasing its electricity use by 52 percent.

The industrial sector decreased its electricity use over the period, in part due to a structural change to less electricity intensive industries and in part due to increases in efficiency. Overall electricity intensity decreased for the sector, with some exceptions. The Smelting & Refining and Pulp & Paper industries increased their electricity use per dollar of product.

Table 11 shows a comparison of how electricity was used in Ontario, by end use, in 1990 versus 2003. The values shown for the Residential and Service sectors are based on data derived from the Office of Energy Efficiency database. The distribution of electricity by end use for the Industrial sector was calculated based on historic values and industry knowledge.

Table 11. Ontario Electricity Use by End Use

	1990	2003 (1)
Industrial Motors (2)	31,973,558	29,002,795
Industrial Lighting (2)	5,937,946	5,386,233
Industrial Process & Electro-technologies (2)	7,765,007	7,043,536
Service Sector Space and Water Heat	1,181,090	1,076,047
Service Sector Cooling	5,627,263	11,801,178
Service Sector Lighting	14,845,321	19,004,744
Service Sector Motors & Equipment	18,309,796	20,197,956
Street lighting	781,322	781,322
Residential Space Heat	9,375,684	10,705,537
Residential Water Heat	8,682,320	7,255,950
Residential Cooling	1,902,127	4,530,707
Residential Base load	24,242,077	25,625,070

Notes:
1. For Commercial and Institutional Sector 2002 values were used as 2003 space heating value appears to be inconsistent.
2. No end use breakdown is available for the Industrial sector. These values assume 70% of energy is used for motors, 23 percent for lighting and 7 percent for electro-technologies (based on industry knowledge).